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Photon02

2 - 5 September 2002
Cardiff International Arena

Industrial Technology Programme 3rd Sept 2002 – 10:00 –Whytes Room

Title: Micro-Engineering with Lasers

by

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Summary

- A brief review of our Microstereolithography System, which led us to be invited into the BRITE EuRAM project
- A brief review of some of the results from the BRITE- EuRAM project which used optical and laser systems to Manufacture Macro/Micro Ceramic components.
- After de-binding and sintering ceramic parts with relative densities of 95% have been produced.

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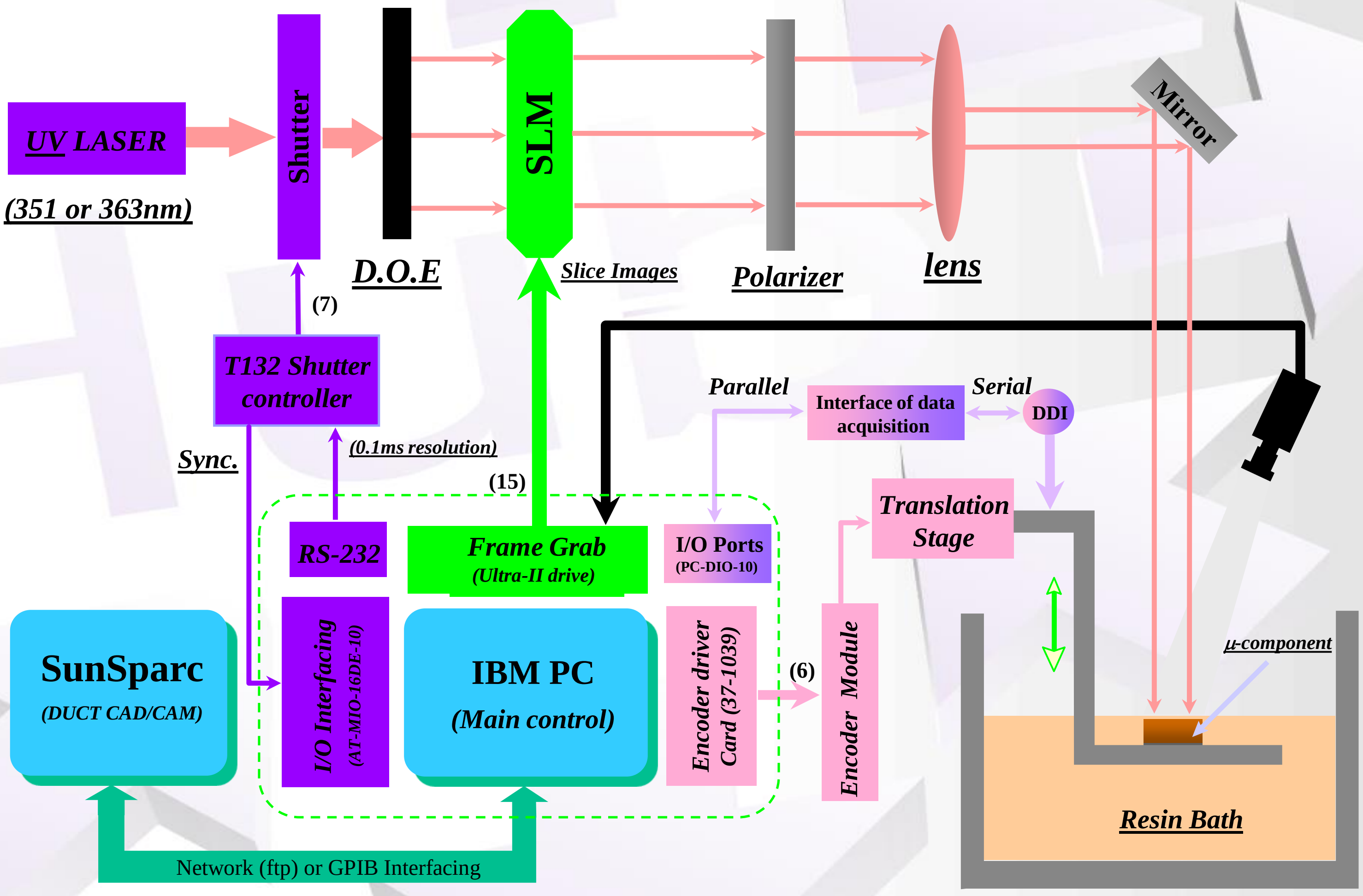
Experimental Set-up

Microstereolithography System Diagram



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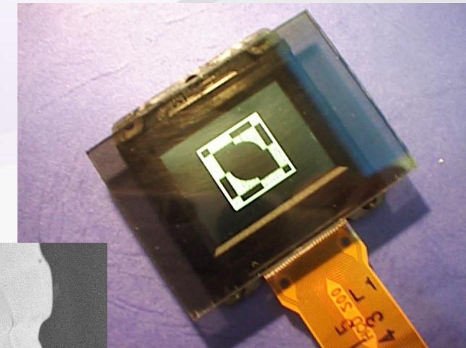
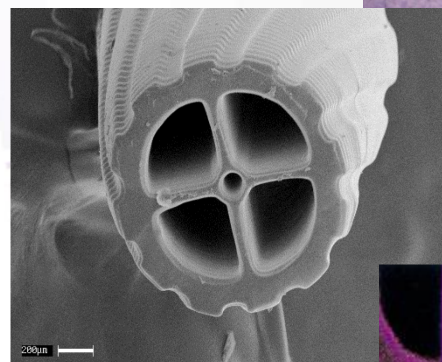
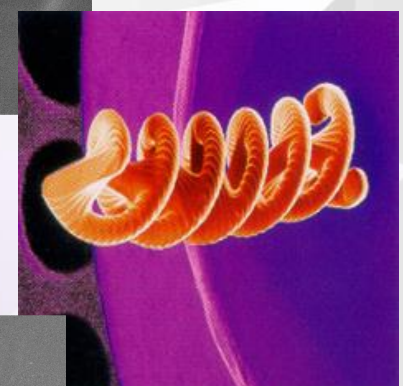
Micro-component Prototyping

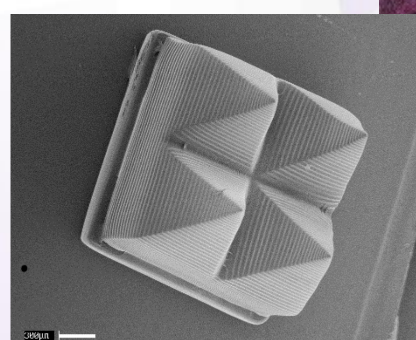
Microstereolithography System



SVGA SLM 800x600 pixels







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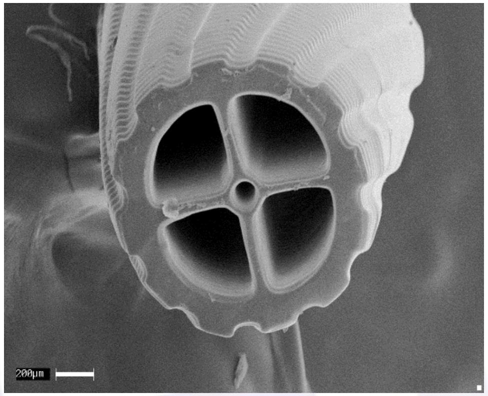
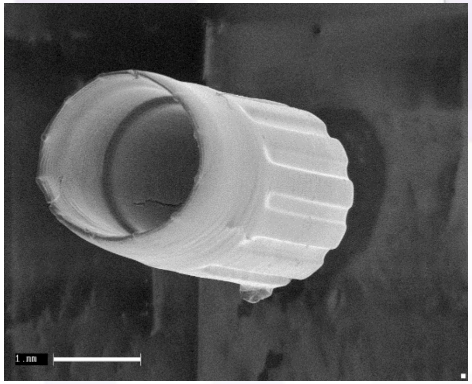
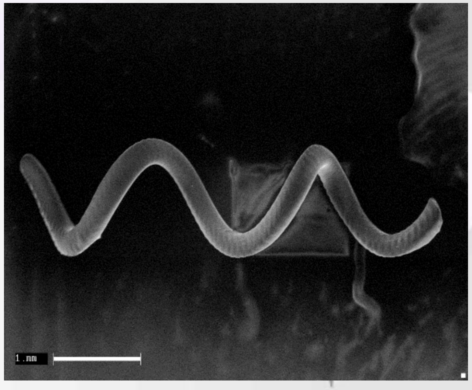
Micro-components



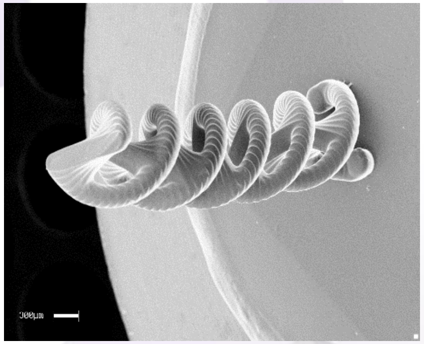
A micro-gear (50 micron layers)



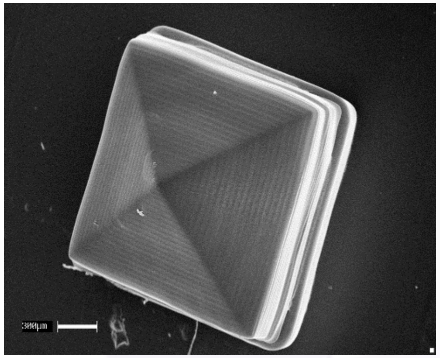
Micro-motor case (50 micron layers)



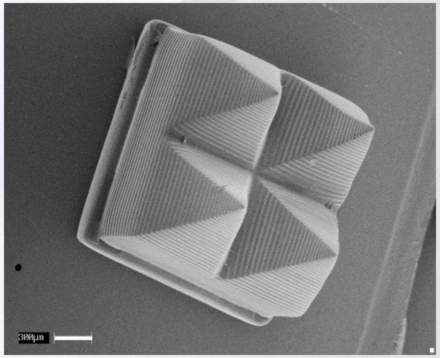
A helix (50 micron layers)



Double helix (50 micron layers)



Micro-pyramid (35 micron layers)



Micro-pyramids (50 micron layers)

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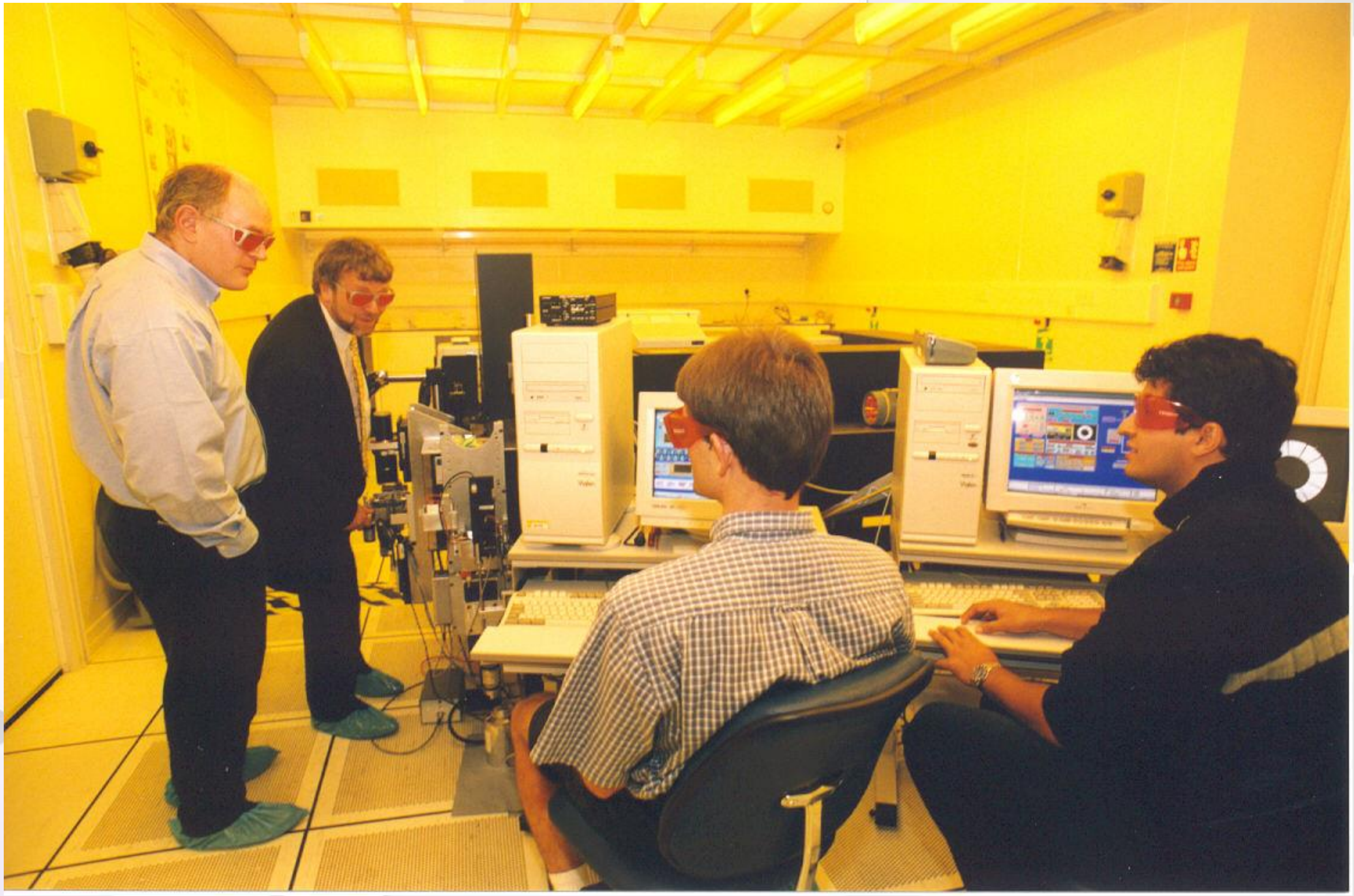
MicroSLA System



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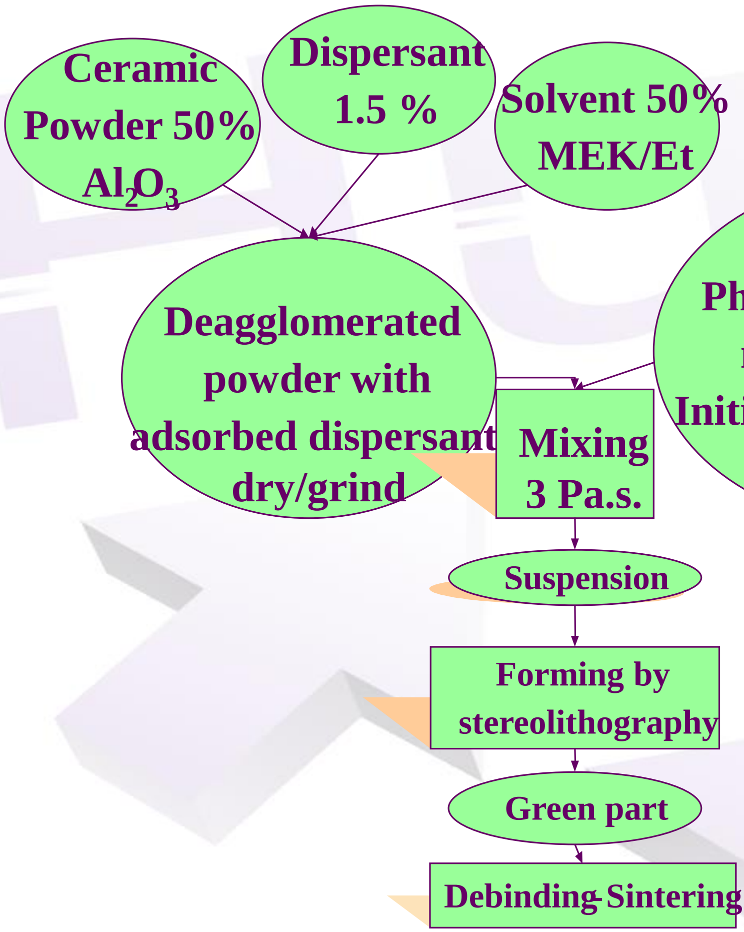
Fabrication of Dense Ceramic Micro - Components

Dispersant: Phostphate ester 1.5% wrt Al_2O_3

Solvent: Ethanol or Acetone 50%



Monomer: hexane-diol-diacrylate (HDDA)

Photoinitiators:

Irgacure 651 (DMPA) absorbs 300-390 nm - 0.5%

Irgacure 819 absorbs up to 450 nm - 0.5%

50 mJ/cm^2 for 100 μm cure depths, resolution of 50 μm

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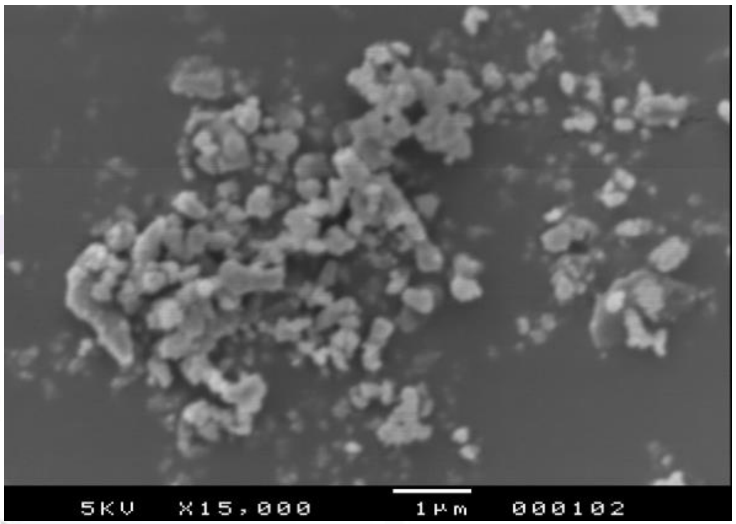
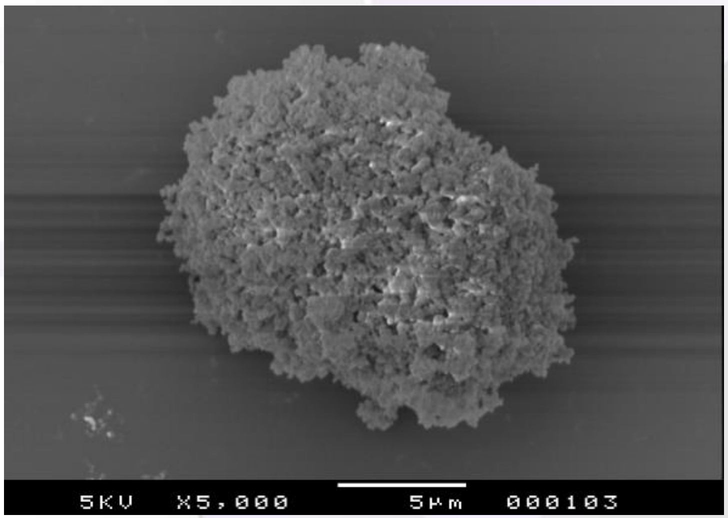
Alumina Powder



Alumina (Al_20_3) Powder: Average diameter 0.5μm; Refractive index 1.7



Aggregate of Al_20_3 powder

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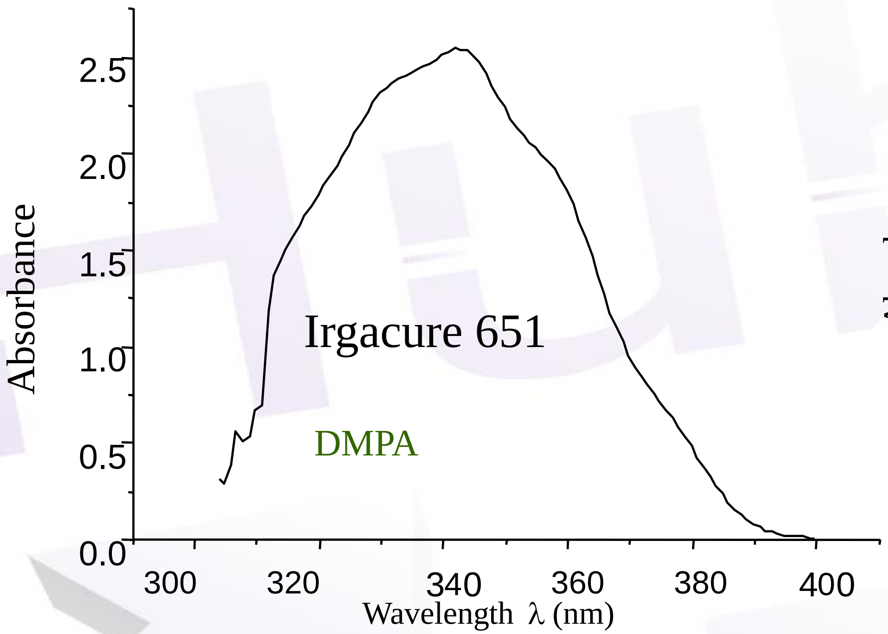
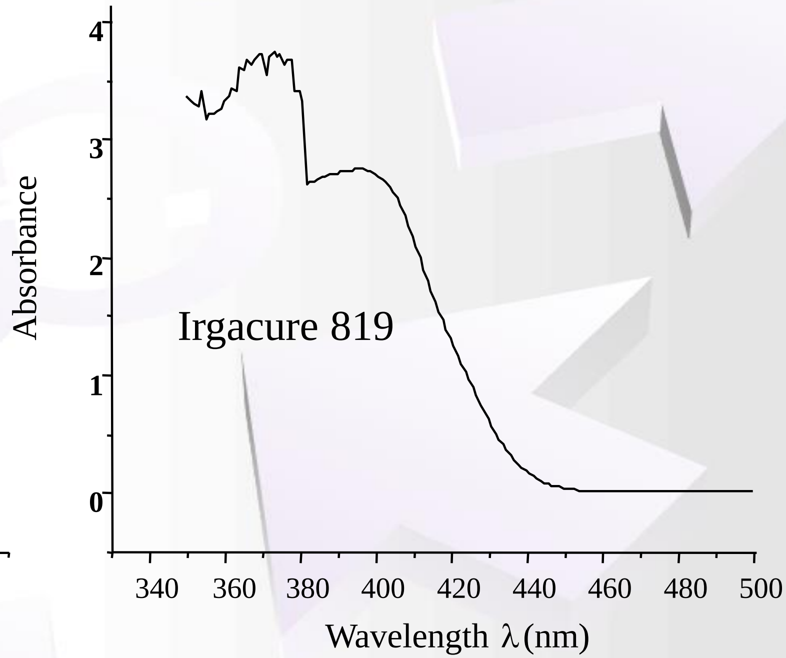
Absorption spectra of photoinitiators for 0.25 wt.% of dispersant in HDDA





Photoinitiators Cover Emission peaks from:

- Hg Lamp - 365nm, 405nm;

- Argon Ion Laser - 363nm;

- Pulsed YAG Lasers - 355nm.

They are soluble up to 5 wt. % into the monomer, 0.5% seems about optimum

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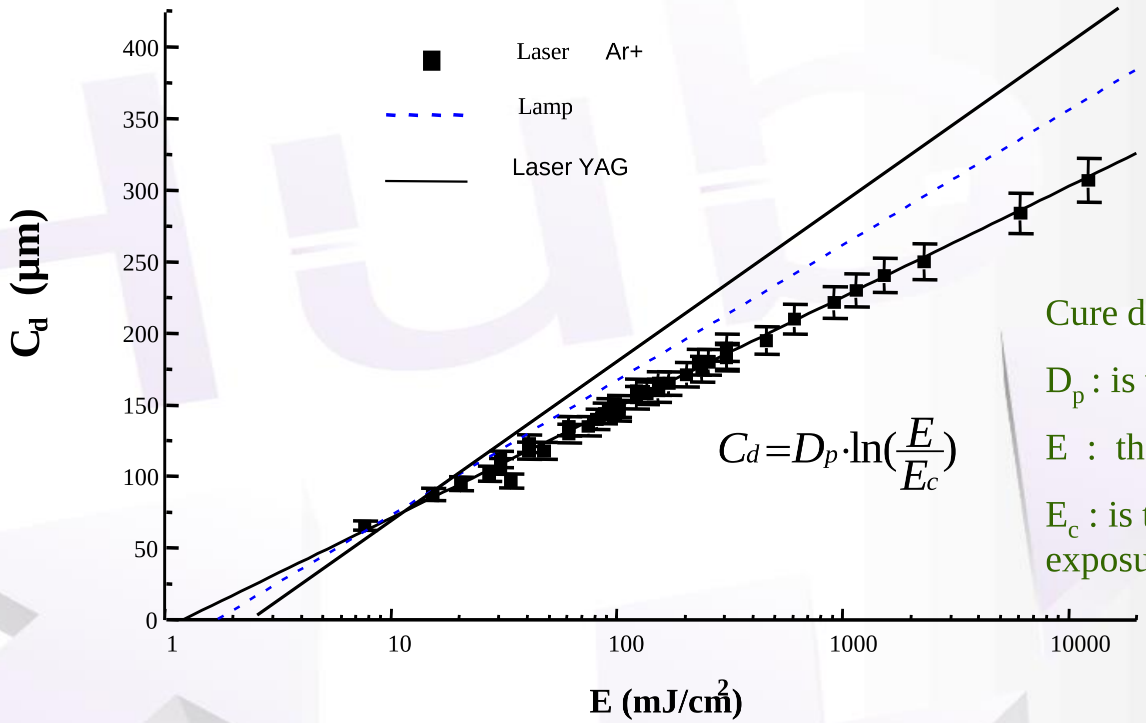
Cure Depth Versus Dose for three Sources



Pulsed YAG Laser - 355nm
Hg Lamp - 365nm
Argon Ion Laser – 363nm

Cure depth C_d (µm)

D_p : is the penetration depth,

E : the exposure or energy at the surface,

E_c : is the critical energy or the minimal exposure dose for the resin to gel.

Cure depth versus dose (80 wt.% alumina, 1 wt.% DMPA)

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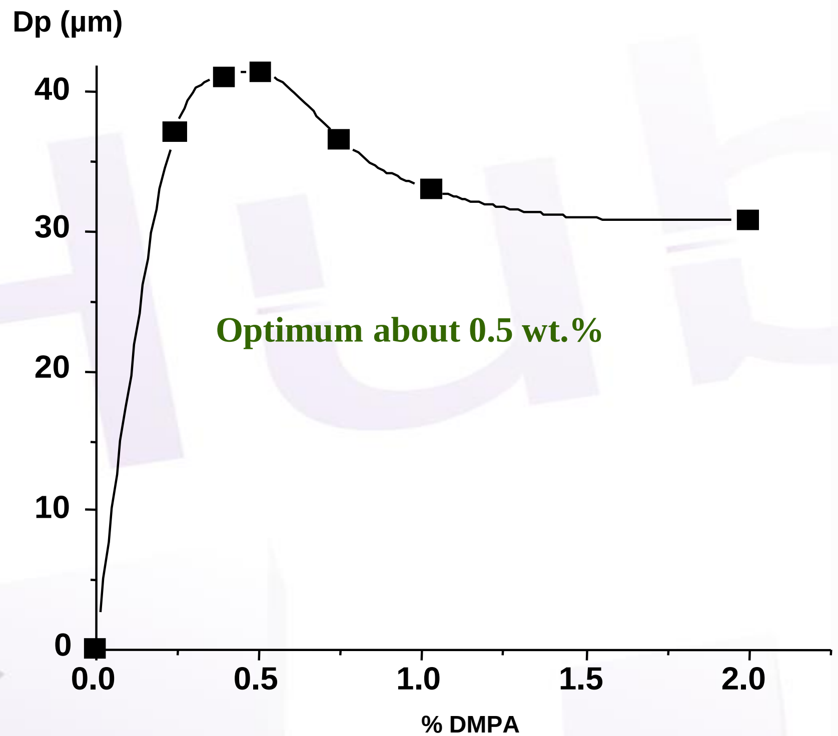
Effect of Photoinitiator on Penetration



Penetration depth versus wt.% photoinitiator ; irradiation with an argon laser at 363 nm

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Influence of the radiation wavelength on the depth of penetration in alumina suspension

Irradiation Conditions	Laser UV (364 nm)	Laser Visible (488 nm)	
Composition in wt. % Alumina	80	Suspension 2: 85	Suspension 1: 80
wt.% Initiator (I 784)	2	3	2.2
D_p (μm)	31	69	105

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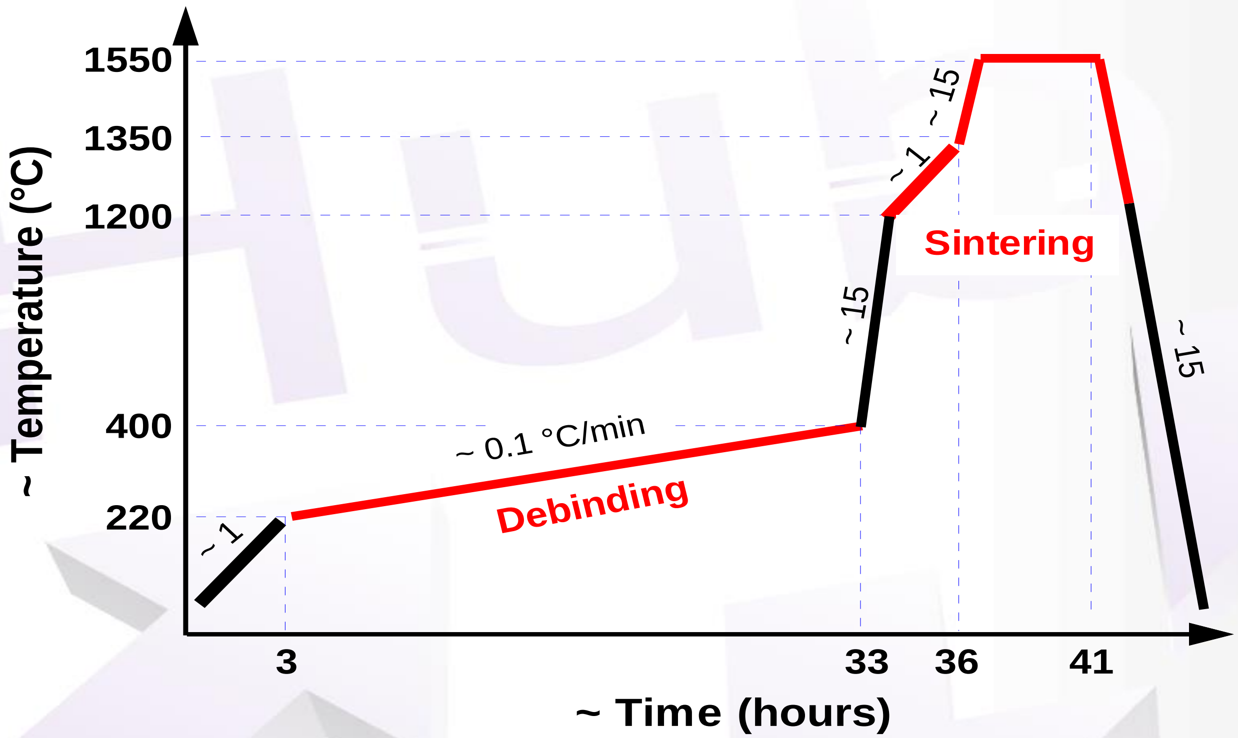
Debinding/Sintering Process



Debinding must be done with a low heating ramp to avoid swelling, distortion and cracking of parts.

Typical thermal treatment for the debinding/sintering process in air

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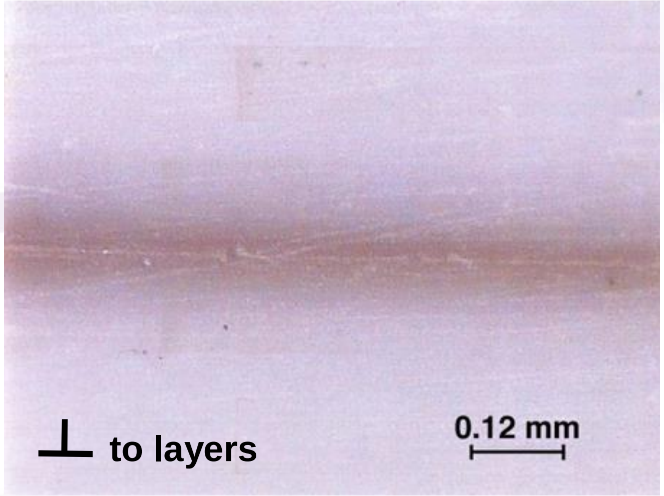
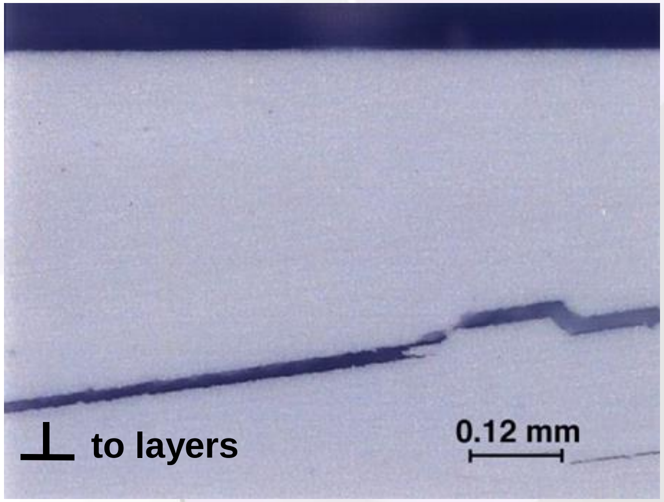
Cracks appear at the Interface between layers if Debinding is too Rapid



Debinding at 5°C/min up to 220°C/10 hours in air



Debinding at 5°C/min up to 600°C/50 min. in air

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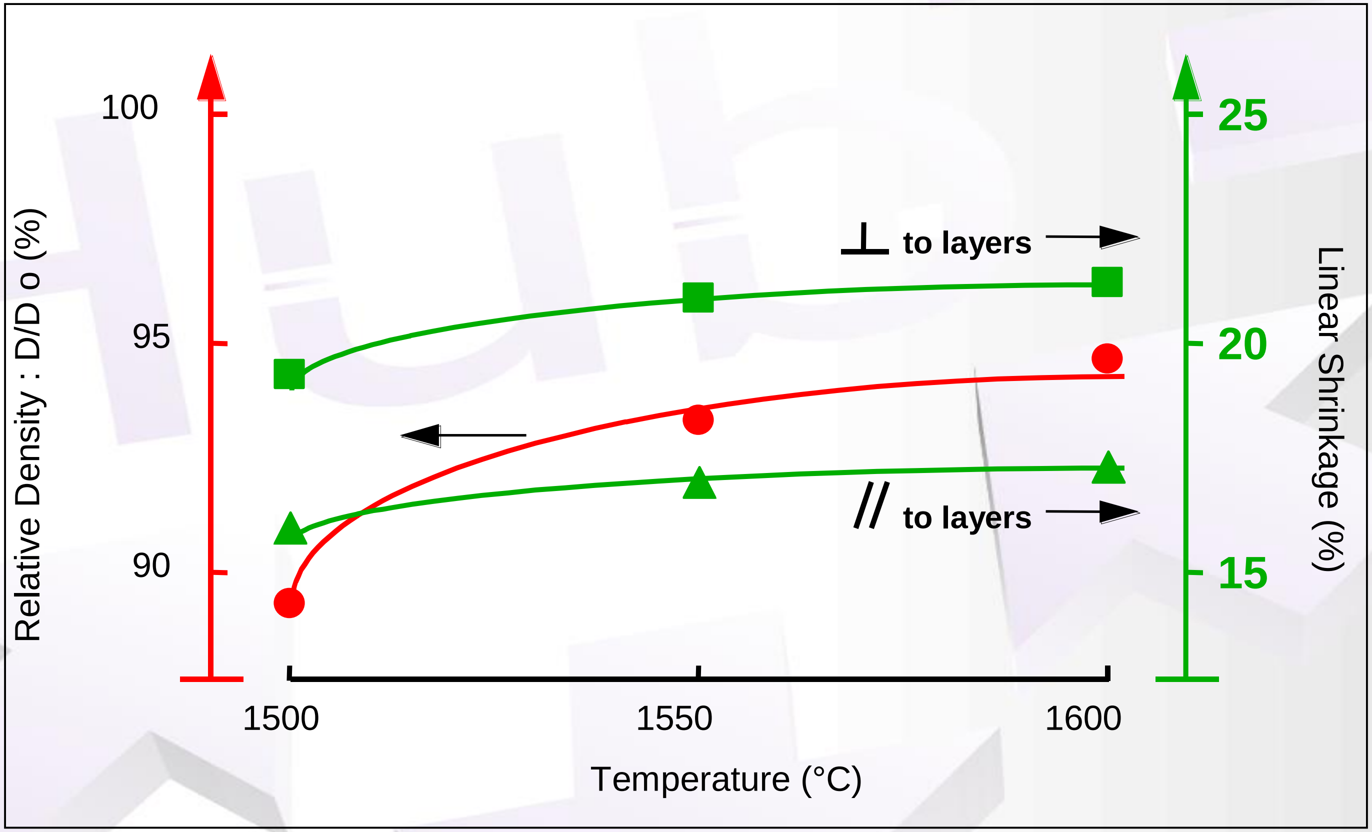
Relative Density and Shrinkage Versus Temperature



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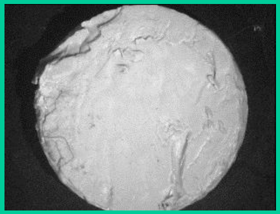
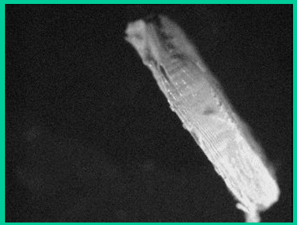
13 Layer Cylinder with 100 micron layers

Some deformation due to faults in deposition layers and bad recoating

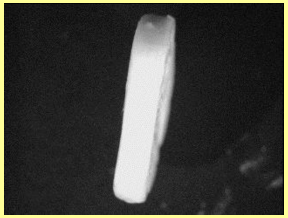
Before Sintering





After Sintering

11% Shrinkage



17% Shrinkage

Demonstration parts sintered at 1600°C for 5 hours

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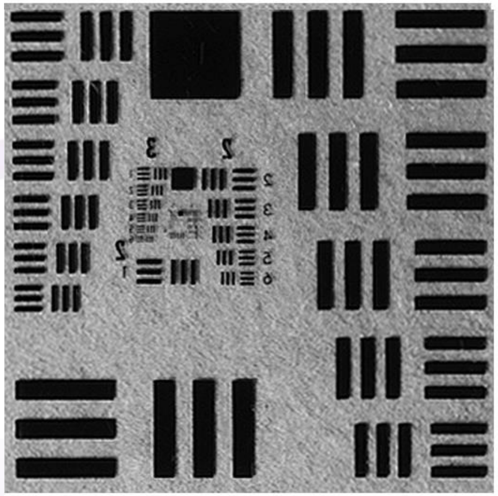
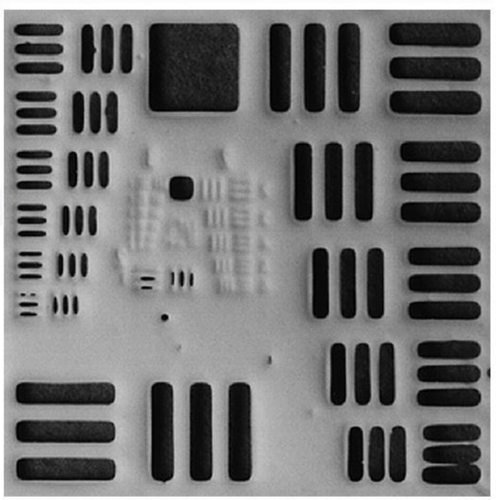
Monolayer - Typical Lateral Resolution 50 microns

Mask



Cured at 365 nm
with Hg Lamp



8mm x 8mm 120 micron thick polymerised layer, resolution 50 microns; 80 wt% alumina, 0.5 wt% DMPA wrt HDDA monomer

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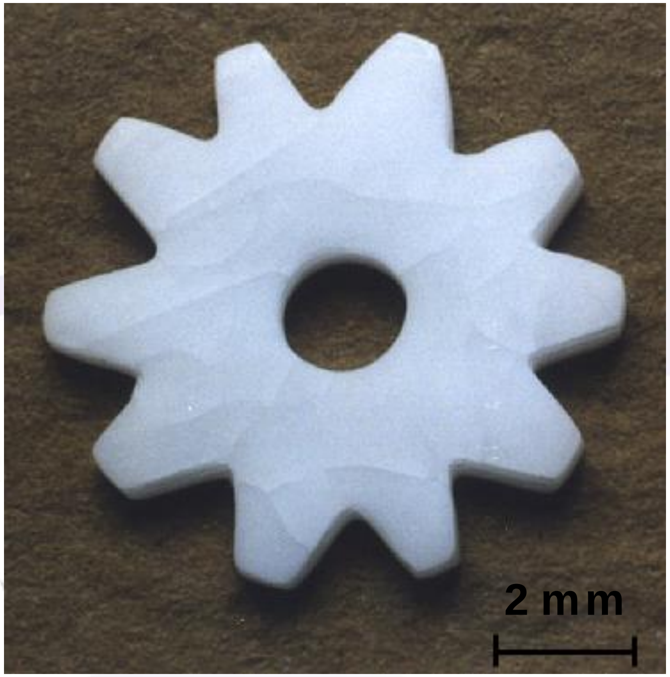
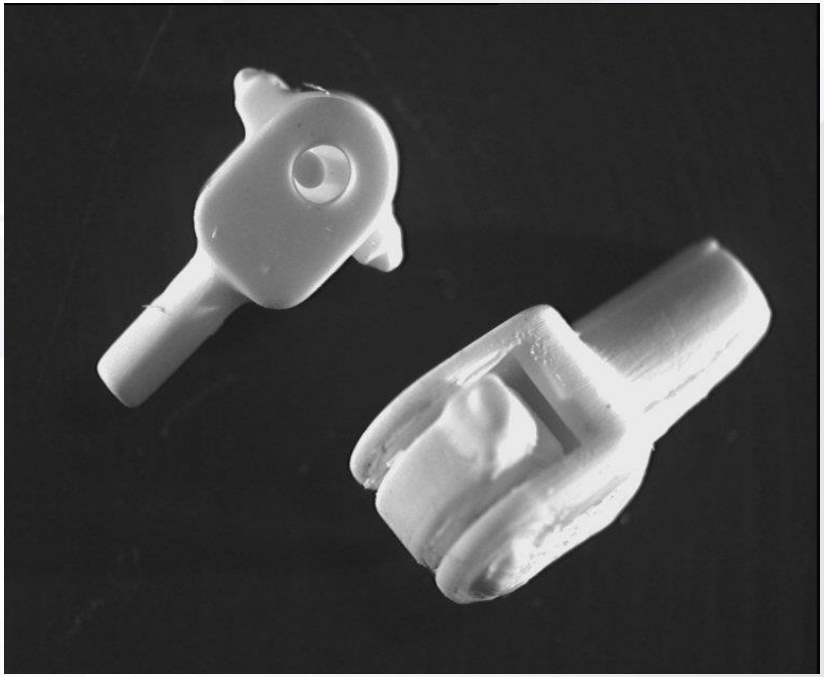
Demonstration Sintered Parts



Demonstration part sintered at 1600°C for 5 hours



Ceramic parts produced with visible source and CRL XGA mask

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Conclusions

- It is possible to formulate highly loaded suspensions containing well-dispersed colloidally stable alumina particles.
- The practical limit for the suspension viscosity, which is about 3 Pa.s, is reached for 85 wt.% of alumina with respect to the photopolymer resin content.
- It has been shown that with an optimised photoinitiator fraction above 0.5 wt. %, and energy densities less than 50 mJ/cm^2 ; 100 µm cured depths can be obtained.
- A good lateral resolution of 50 μm has been demonstrated.

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Conclusions

- The modification of the formulation by changing the amount of photoinitiator allows the depth of penetration to be increased by a factor 2 or 3 depending on the alumina loading.
- Satisfactory parts with 100 μm thick layers were built with a 20 seconds exposure and a laser power of 2 W.
- Ceramics with relative densities up to 95% have been produced.
- Some sample cracking occurred during the final thermal processes, the control of this process requires further investigation.

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References

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